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GROUP

CANADIAN PATENT

LINER EXPANDER

Joe C. Stall, Tulsa, Oklahoma, U.S.A.

Granted to Pan American Petroleum Corporation, Tulsa, Oklahoma, U.S.A.

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APPLICATION No. 897, 460

FILED PRIORITY DATE

No. OF CLAIMS

LINER EXPANDER

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This invention relates to a constant force spring device, and more particularly, to a device for expanding a metallic liner wherein an expanding die is urged against the liner by a constant force spring device.

Heretofore, a method and apparatus have been developed for installing an expanded metallic liner in an oil well or other conduit. Typically, a corrugated steel liner is inserted in a conduit which is to be lined, the greatest peripheral dimension of the liner being slightly less than the inside diameter of the conduit. An expanding tool is passed through the liner placed in the conduit, and a first-stage expanding die causes a gross plastic deformation of the liner, which is expanded outwardly against the inside of the conduit. A second-stage die on the tool then provides an additional finer deformation of the liner to provide a smoother, more finished surface on the inside of the liner and to assure more complete contact between the conduit and the liner. In a typical design of this type expanding tool, the frictional drag of the first-stage die supplies the expanding force for the second-stage die, which expanding force is a direct function of the strength, or wall thickness, of the conduit in which the liner is being installed. For example, in lining oil well casing, heavy wall casing may cause a very high frictional force which results in excessive pressure being required to push the expander through the liner. The application of the great forces required may result in rupture of the casing or in breaking the installing tool. In instances where the internal diameter of the conduit is somewhat less than that anticipated, the resulting forces can cause the tool to become stuck in the casing, or otherwise cause damage to the casing and the tool. In other designs, such as where a cantilever spring arrangement is employed in connection with the secondstage die, various difficulties are encountered in obtaining a spring mechanism having the desired strength in combination with the other spring characteristics, and with the tool dragging against the inside wall of the conduit after being passed through the liner.

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Since tools of the type mentioned above often are employed in wells deep in the ground, it is highly preferable that a tool be used which under no circumstances will become stuck in the well or cause damage to the well. Any such trouble occurring in a well can result in considerable loss in time and great expense in making repairs.

An object of the present invention is a device for applying a constant force to an expanding die or other similar apparatus so that a preselected maximum force is exerted against a work piece. Another object is an improved expanding tool for installing metallic liners in a conduit, which expanding tool can apply no greater than a predetermined force to the liner being installed in the conduit. Still another object of the invention is an economical and easily fabricated constant force spring device. A further object is a rugged, easy-to-operate expanding tool employing such a spring device. These and other objects of the invention will become apparent by reference to the following description of the invention.

In accordance with the present invention there is provided a constant force spring device which comprises a body member, an elongated column element adjacent said body member, bearing plate members contacting the two ends of said column at least one of said bearing plate members being longitudinally movable in respect of the other and stop means on said body member to limit the deflection of said column element to prevent permanent deformation of said column element upon the application of a compressive load thereto. In one embodiment of the invention, the foregoing constant force spring device is employed in a tool for expanding a metallic liner inside a conduit, said constant force spring device being positioned on said tool to urge an expanding die member against the liner being installed in the conduit by a substantially constant force.

My invention will be better understood by reference to the following description and the accompanying drawings wherein:

Figures 1A, 1B and 1C, taken together, constitute a partial sectional view of a preferred embodiment of a liner expanding tool according to the present invention; and

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Figure 2 is a sectional view of the apparatus of Figure 1A taken at line 2-2; and

Figure 3 is a typical plot of applied Load versus Deflection for the constant force spring device of the invention.

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Referring to the drawings, Figure 1A is the bottom portion of a liner expanding tool for use in installing a metallic liner in a well, while Figure 1B illustrates the middle section of such a tool and Figure 1C represents the upper section of the tool. The expanding tool 11 is attached to standard well tubing 12 by coupling 13 and, typically, may be lowered from the surface through a well casing (not shown) to a point in the casing at which it is desired to install a metallic liner. Before inserting the tool into the well, an elongated vertically corrugated liner 14 fabricated from mild steel, or other suitable malleable material, is placed on the tool. The corrugated liner is secured in position by contact at its upper end with a cylindrical shoulder member 16 and, at its lower end by contact with a first-stage expanding die 17 in the form of a truncated circular cone which serves as a firststage expanding die in the manner hereinafter described. The expanding die is fixedly attached to a centrally located, elongated cylindrical hollow shaft 18 which forms a portion of the body of the tool. As shown, the expanding die 17 is held in place between a lower shoulder 19 and collar 21 threaded onto the shaft. A plurality of movable arms 22, preferably provided with outwardly enlarged portions 23 near the top, are disposed in the form of a cylinder around shaft 18. The enlarged portions of the arms 23 upon being moved outwardly contact the liner to perform the final step of expanding the corrugated liner into a substantially cylindrical shape. The arm members 22 are pivotally attached to the shaft so as to be movable outwardly from the shaft by a tapered expanding member 24 slidably positioned on the shaft to serve as a second-stage expander. The surface of the member 24, as shown, moves upwardly along the shaft to engage with the arms and move them outwardly. Advantageously, the inside surfaces of the arms 22 and the outside surface of expanding member 24 form mating sections, typically octagonal in shape. The expansion of the arm members is controlled by the position of the member 24 which moves upwardly

until it contacts shoulder 26 provided on the shaft. As member 24 moves in a downwardly direction arms 22 fold inwardly toward the shaft. The expanding arms 22 are held in place on the shaft by collar 27 and circular groove 28 provided on the shaft.

The expanding tool, comprising the first-stage die and the secondstage die is drawn through the liner to expand it in place in the casing. The
first-stage die provides a gross deformation of the liner so that it is
expanded outwardly against the wall of the casing. The second-stage die then
passes through the liner and performs the final expansion to smooth the inner
surface of the liner and to provide more even contact between the liner and
the wall of the casing and effect a fluid-tight seal.

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In operation, the liner setting tool is assembled at the surface, as described above, and a glass cloth saturated with a resinous material may be wrapped around the corrugated tube to form the liner. The assembly is lowered into the well at the location at which the liner is to be set. A liquid, such as oil, is then pumped under pressure down the well tubing and flows through the passageway 29 provided in polished rod 31, through ports 32 and into cylinder 33 connected to the upper end of the shoulder 16. Upon the application of fluid pressure to the cylinder, the piston 34 secured to polished rod 31 moves upwardly in cylinder 33. As shown, rod 36 connects polished rod 31 and shaft 18 upon which is mounted the first-stage expanding die 17. When the piston 34 moves upwardly through the cylinder 33 the expanding die 17 and the secondstage die 22 are drawn upwardly into the corrugated liner 14 and "iron out" the corrugations in the liner, so that the expanded liner may contact the inside wall of the casing in which it is being installed. Positioned on the shaft below the expanding member 24 is a constant force spring member 37 which is employed to urge the expanding member against the expanding arms 22 with a substantially constant force. The force exerted against the arm members being substantially constant, the force transmitted through the arm members to the liner and to the casing will be substantially constant so that either sticking of the tool in the casing or rupture of the casing is precluded. Of course, the force provided by the spring member is preselected so that the frictional

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forces between the tool and the liner and the pressure exerted against the casing are maintained at predetermined safe levels. The constant force spring member assures that the contact pressure between the liner forming portion 25 of the arms 22 is great enough to provide the desired deformation of the casing, while preventing damage to the casing or to the tool.

The constant force spring member 37 is slidably mounted on the shaft 18 and held between the expanding element 24 and a cylindrical lower shoulder member 38 forming a portion of a differential sorew element 39 which transmits the loading on spring member 37 to shaft member 18. The differential screw element comprises shaft member 18 on the outside of which are cut male threads 18a, the lower shoulder member 38 provided with female threads 38a and thimble member 41 provided with threads 41a and 41b on the outside and the inside, respectively, to engage with threads on the shaft and the shoulder. The two sets of threads are coarse, such as square, modified square, or Acme threads, to withstand very high loads and differ in pitch so that shoulder 38 is moved upwardly on the shaft 18 when the shaft is revolved relative to thimble 41. The shoulder 38 is secured to the shaft 18 by splines 45 so that it can slide longitudinally, but it is not free to rotate on the shaft. Fixedly attached to the lower end of the thimble is a friction member, such as bow springs 42, a hydraulically actuated friction pad, or other such device for frictionally engaging with the inside wall of the conduit to secure the thimble against rotation with respect to the shaft. Preferably, the direction of the shoulder member threads 38a is the same as that of the shaft threads 18a, e.g. righthand threads, and the pitch, or lead, of threads 18a is slightly greater than that of threads 38s, with the pitch ratio being close to unity. In this manner, clock-wise revolution of the shaft relative to the thimble causes shoulder member 38 to advance upward slightly and a compression load is exerted upwardly on spring element 37 to cause buckling. For example, one satisfactory differential screw was made up using five and one-half threads/inch square threads on a shaft approximately 1.7-inch outside diameter and five and threequarters threads/inch square threads on a shoulder approximately 2.5-inches inside dismeter.

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Constant force spring element 37 comprises column element 43, advantageously consisting of a plurality of elongated columns disposed around shaft 18. Upper bearing plate member 44 is in contact with the upper ends of the columns and is slidably positioned on shaft 18 to transmit the force of the spring longitudinally against the bottom end of expander member 24. Lower bearing plate member 46 contacts the lower ends of the columns and is moved upwardly along the shaft by longitudinal movement of lower shoulder 38 as a result of revolving differential screw element 39. Grooves 47 are provided in each of the bearing plates, to form an upper race and a lower race, into which the ends of the columns are inserted. These grooves may be shaped to conform with the shape of the column ends if desired. A cover 48 may be employed to exclude foreign matter from the spring mechanism and to protect the spring.

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A means for limiting the deflection of the columns is required. Although the column element functions in a buckled condition, application of excessive compressive load thereto would cause total failure or rupture of the columns. Therefore, a pair of stops 49 and 49a are provided for this purpose. As shown, the stops are rigidly connected to the bearing plates, and, in effect comprise upper and lower limiting sleeves positioned on the shaft to slide longitudinally thereon. The ends of the stops may move toward, or away from, each other as the load on the spring member varies. Lower sleeve 49a is prevented from moving down by lower shoulder 38 connected to the shaft 18. However, the spacing between the ends is such as to limit the longitudinal travel of the bearing plate members as they move together to prevent permanent deformation of the column element 43. Various alternative means for preventing damage to the column element may also be employed. For example, pins or rings mounted on the shaft may serve as stops, or the cover 48 provided with suitable connections may be employed for this purpose to limit longitudinal and/or lateral deflection of columns.

The columns of the column element 43 may be arranged around the shaft 18, which as shown here forms a portion of the body of the spring device, with ends of the columns fitted in the races 47. The columns may be

fitted closely together as shown, or may be spaced around the race, with separators used between them to maintain the desired spacing. The number of columns employed will depend upon column characteristics and the materials of construction. For example, the slenderness ratio of the column may be varied widely, and the column ends may be round, flat, fixed or hinged. The preferred construction is a thin, slender column with rounded ends, free to move within the races shaped to the curvature of the column ends. Materials which may be satisfactorily employed for the columns are carbon and low alloy steels, chromium and nickel-chromium stainless steels, various copper base alloys, such 10 as phosphor bronze, beryllium copper, the high nickel alloys and other similar materials providing satisfactory mechanical properties. Typically, the individual columns are of long rectangular cross-section, with the width being greater than the thickness, and arranged so that the wider face of the columns is normal to the diameter of the shaft. Thus, with sufficient compression loading, the columns buckle, and bend about the axis having the least moment of inertia, e.g., outwardly away from the shaft 13.

For example, a group of columns 0.167-inch thick by 0.438-inch wide by 10.626-inches long, with the ends rounded, were fabricated from A.I.S.I 4340 steel, quenched and drawn at 575°F. Each column was found to require a 20 critical compression loading of 450 pounds in order to buckle the column. After buckling, the columns were found to have a very flat spring characteristic, as shown in Figure 3, wherein P_c is the critical buckling load and point C represents the load and deflection at which the stress in the extreme fibers of the column exceed the yield point of the material. Theoretically, the shape of this spring characteristic curve is described by curve OA'ABC. Actually, this curve is described by OABC due to friction in the system. Points A end B represent typical working limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flexing cycles are not anticipated, a working stress just below the yield point may be used, while with a great number of flexures, the working stress may be held to less than the endurance limit of the material of construction. In the above-mentioned tests, the lateral deflection was limited to

approximately one inch, at which the longitudinal deflection was approximately: 0.225 inches. From zero deflection to the maximum deflection, the 450-pound loading was found to be substantially constant.

In another test a spring device was built, as shown, employing 20 columns, each having a critical buckling load of 1250 pounds. The lateral deflection was limited between 0 and about 1.00 inches by appropriately positioning the stops. Upon compressional loading, the spring element buckled at substantially 25,000 pounds and from a longitudinal deflection of 0.04 inches (buckling) to about 0.15 inches the load remained substantially at 25,000 pounds.

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Of course, in designing a spring element as above it is advantageous to obtain the greatest possible value of longitudinal deflection for specified values of lateral deflection and critical buckling load, while maintaining the stress level in the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 1B and 2, with multiple flat members making up each column.

In the operation of the above expanding tool for setting a liner in well casing, the made-up tool is lowered into the well as mentioned above, with the arms 22 in the retracted position. When the tool is at the desired level, the well tubing is revolved. The friction member 42 engages with the wall of the casing and prevents thimble 41 from revolving. With several revolutions of the tubing, lower shoulder 38 is moved upwardly by differential screw 39 to buckle spring element 37 which has a predetermined critical buckling load. This load is transmitted upwardly against the lower end of expander 24, and its tapered surface is engaged with the tapered surface on the inside of the arms 22 to urge the arms outwardly with a substantially constant force proportional to the critical buckling load of the spring element. Subsequently, the expanding tool is passed through the liner to expand it in the casing in the manner described hereinbefore.

The foregoing description of a preferred embodiment of my invention has been given for the purpose of exemplification. It will be understood that various modifications in the details of construction will become apparent to

the artisan from the description, and, as such, these fall within the spirit and scope of my invention.

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I CLAIM:

- 1. A device for expanding a metallic liner inside a conduit which device comprises a shaft element, an expanding die member attached to said shaft element, said die member comprising a movable liner-forming member Ł positioned on said shaft and being radially movable in respect thereof to contact said liner, an expander member slidably positioned on said shaft between said shaft and said die member to move said liner-forming member from said shaft, and a constant force spring member positioned on said shaft to contact said expander member and to maintain said expander member against said liner-forming member, whereby said liner-forming member is urged against said liner by a substantially constant force.
 - 2. In a device for installing an expanded metallic liner in a conduit wherein an expanding die is moved through a liner positioned in said conduit to expand said liner: a cylindrical shaft element, an expanding die member attached to said shaft, said die member comprising a plurality of arm members disposed around said shaft and being pivotable outwardly therefrom to contact said liner, a cone member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft, and a constant force spring member positioned on said shaft to contact said cone member and to maintain said cone member in contact with said arm members, whereby said arm members are urged outwardly by a substantially constant force.
 - 3. The device of Claim 2 wherein said constant force spring member comprises a plurality of columns disposed around said shaft, a first bearing plate member and a second bearing plate member, each of said bearing plate members contacting opposite ends of said columns, at least one of said bearing plate members being movably positioned on said shaft and being in contact with said come member, stop means connected to said shaft to limit the axial travel of said movable bearing plate member along said shaft, and compression means for maintaining a lateral deflection in said columns.

- 1 4. The device of Claim 3 wherein said compression means comprises
 2 a differential screw connecting said spring member and said shaft.
- 5. The device of Claim 3 wherein said stop means comprises a
 sleeve-like element connected to said movable bearing plate member and
 slidably positioned on said shaft and a member connected to said shaft to
 limit the travel of said sleeve-like element.
- 6. The device of Claim 3 wherein said columns have a rectangular cross-section, the width being greater than the thickness, and having the wider face normal to the diameter of said chaft.
 - 7. A device for installing an expanded metallic liner in a conduit which comprises a cylindrical shaft element; an expanding die member mounted on said shaft, said die member comprising a plurality of arm members disposed circumferentially around the outside of said shaft and being pivotable outwardly therefrom to contact the liner; a conical expanding member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft; a plurality of slender columns, each having a long rectangular cross-section and disposed circumferentially about said shaft; an upper bearing plate member and a lower bearing plate member, each slidably positioned on said shaft and contacting opposite ends of said columns; limiting sleeves attached to each of said bearing plate members and slidably positioned on said shaft; a shoulder member on said shaft; a differential screw element connecting said shoulder and said shaft to apply a buckling load to said columns; said shoulder being engageable with the limiting sleeve connected to said lower bearing plate member, whereby the axial travel of said bearing plate members is limited; said column members transmitting their buckling load to said arm members to urge said arm members outwardly with a substantially constant force.

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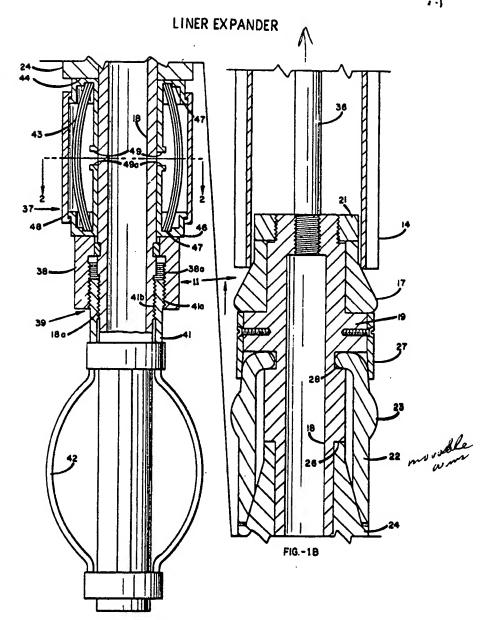
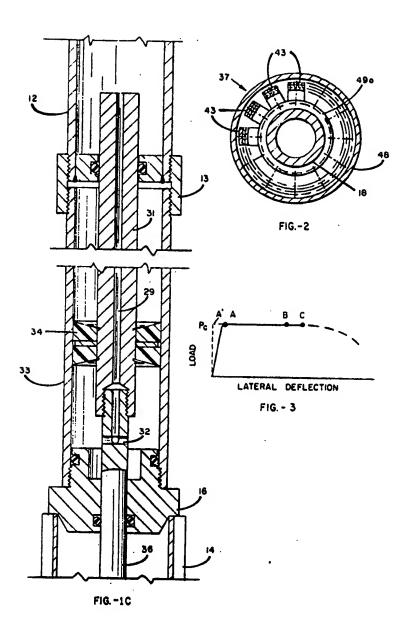


FIG.-1A



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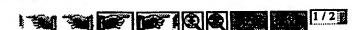
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1. A device for expending a metallic line; houde a conduct which device acoprison a shift alment, on aspending the member abisabed to maid shaft cleases, stid die number comprising a movelle liner-forming number positioned on said shaft and being cartally moveble in respect thereof to contact sais liner, as expender momber aligably positioned on said short 6 between said stack and sold the member to move said liner-francing member from said shift, and a constant form spring number positioned on male staff. to contact mid expenses symbor and to extense said expenses number assistate said liner-forming surbor, whereby said hiner-forming number to urgod against said like by a smietantially constant force.

2. In a device for installing an expended astallic liner in a equitit wherein an expanding the is moved through a liner positioned in said hat to mustod mid liners a cylindrical staff element, an expending sic mother attached to said shaft, said die souber comprising a plausifity of arm disposed around said shoth and being physicals subsavily therefrom to nested finer, a come member slightly positioned on said shall between exid shaft and said are mesters to urps said are mesters collegely from said nd a constant force spring member positioned on sale, staff to contest " said otes member and to maintain said ours member in scataot with said are members, whereby said now members are surged outsardly by a substantially

3. The fertice of Claim 2 shands said equation force spring number comprises a plumbility of ethnica Risposed around said shaft, a store boaring ther and a percent bearing plate streter, mad of said bearing pixts ers contecting opposite onto of said columns, at least one of said bearing ers being movehly positioned on said sheft and being in contact with said come number, stop monte connected to said start to limit the artal The travel of said movemble boaries plate number along said shaft, and compression meens for unintaining a internal deplection in sold columns.

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My investion will be better understook by reference to the following description and the mesospenying drawings wherein:

Figure 14, 18 and 16, taken together, convictute a portial sectional view of a preferred embediment of a liner expending tool assurding to the present investion; and

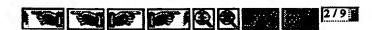




Figure 2 to a sentinual view of the apparatus of Figure 1A tabes at

Figure 5 is a typical plot of applied lock versus Deflection for the constent force spring device of the Levestion.

Referring to the drawings, Figure 15 is the bottom portion of a liner expending took for one in installing a metallic liner is a well, while Figure 19 Cilestrator the middle section of such a tool and Figure 10 represents the upper sestion of the tool. The expending took it is attended to stantist well fulding 15 by ampling 15 out, typically, may be lessend from the surface through a well ensing (not shown) to a potent in the suring at which it is desired to install a notallic liner. Before inserting the test late the well, an alongsted sertically corrupted liner in Cabricated Iron aild stand, or multiple mallockle meterial, to placed on the tool. The corregated liner is secured in position by centers at its upper end with a cylindrical shoulder masher 16 and, at the lower and by contact with a first-stage espainting dis 17 in the form of a trumested circular core which serves as a firstsings expending die in the server bareinefter described. The espanding die is fixedly estanted to a controlly located, elemented spinerical bollow shaft 18 which forms a parties of the body of the tool. As shows, the expending sie 1720 is half in place between a lower shoulder 19 and coller 21 threaded onto the short. . A plurality or movehic arms 25, preserably provided with outsandly salarged portions 25 mar the top; wie disposed in the form of a sylinder around that's 18. The onlarged purbloss of the sens 23 upon being moved outvarily equiest the liner to profess the final stop of expending the excepted ... liner into a enterestially sylindrical shape. The are eastern H2 are pivotally etiqued to the staff on no to be movehle pubmetly from the shaft by a tapared expending member 26 although positioned on the sheft to serve as a se expender. The excises of the mesher Ms, as shown, moves upwardly along the start to sagage with the arms and more them outwardly. Advantageously, the 30 incide surfaces of the area 22 and the outside emface of expending master 24 form sering sestions, typically octogonal in shape. The oxyention of the arm ers is controlled by the position of the member 24 rich moves upwardly



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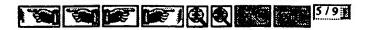
The expending tool, comprising the first-stage die and the continuous tage die is drawn through the liner to expend to the place in the continuous first-stage die prevides a gross disformation of the liner so that it is expended outwardly against the well of the seeing. The second-stage die them passes through the liner and performs the final expension to enouth the inner surface of the liner and to wresten more even contact brivess tak liner and the well of the casing and effect a finid-tight seel.

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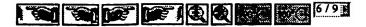




forces between the tool and the liner and the pressure enerted against the oneing are amintalized at pressurations safe levels. The constant forces spring maker sammes that the context pressure between the liner forming portion 25 of the same 22 is great enough to provide the desired deformation of the sading, while preventing demagn to the saming or to the tool.

The seastest force spring easter 77 is alidebly sounted on the shaft 18 and hald between the expending alongst 28 and a sylindrical lower checker under 35 ferming a portion of a differential server alonest 39 which transmits the hooling on opting number 37 to shaft number 18. The differential server alonest comprises shaft under 18 on the outside of which are out note threads 18a, the lower shaft number 18 provided with typical threads 35a and thinkle number 31 provided with threads all and \$10 as the criside and the inside, respectively, to seems with threads on the shaft and the shoulder. The two cots of threads are source, such as square, notified square, or Ame threads, to withertand very high loads and differ in pitch so that shoulder 35 is moved upwardly on the shaft 10 when the shaft is revoived relative to thinkle \$1. The checker 35 is seemed to the shaft 18 to splines \$5 so that it can alide longitudinally, but it is not free to rotate on the shaft. Finally attached to the lower sed of the thinkle is a friction number, such as but springs \$2, a hydramically estimated friction past, or other such device for frictionally magazing with the inside until of the sandwit to occurs the thinkle squinet trotation with respect to the shaft. Preferably, the direction of the shoulder number for the shoulder set that the pitch rotate being alone to unity. In these moment, clock-wise revolution of the shaft relative to the thinkle square shoulder square 35 to advance upward aligntly on a congression load is exerted upwarely on apring alaemat 37 to unsee buckling. For example, one retistratory introde on a shaft approximately 1.7-inch outside dissector and five and threads/inch aquare threads/inch square inside dissector and five and threads/inch aquare inside dissector.



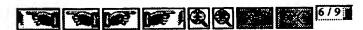


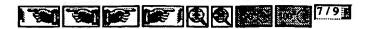
Disatest force spring element 37 comprises union element \$5, siventageonally continuing of a planelity of alongsied column disposed around shorts
18. Upper bearing plate number th in is contact with the apper ends of the
solumn and is although positioned on short 18 to trements the force of the
spring longitudinally against the bottom and of expendes contact the force of the
spring plate senter to contact the lover sense of the columns and is noved
specially along the short by langitudinal necessary of loser shoulder 59 on a
result of revolving differential server element 39. Greaves 17 are provided
in such of the bearing plates, to form an upper race set a larger race, into
which the ends of the column are inserted. These greaves may be shaped to
contarn with the shape of the nolumn units if desired. A cover 48 any be
employed to amplifie foreign matter from the spring mechanics and to protect

A needs for limiting the defination of the column to required. Although the column element functions in a buckled condition, application of . propertive compressive load thereto would sense total failure or repture of the columns. Therefore, a pair of stope by and bya are provided for this purpose. As shown, the stope are rigidly connected to the bearing plates, and, in effort comprise upper and lower limiting sleaves positioned on the shaft to alide longitudinally thereon. The under of the stops may some toward, or sun; from, each other so the look on the spring number verted. Lever slaces age ictal from speling down by laster aboutless 38 accessored to the about 18. ver, the specing between the suds in much he to limit the longitudinal travel of the bearing plate members on they move together to prevent personnt deformation of the solumn almost \$5. Wartons alternative mame for preventing damage to the column element way also be employed. For example, year or rings sometad on the chaft may serve as atops, or the cover 48 provides with estable connections may be suplement for this purpose to limit longitudinal end/or lateral seriection of columns.

The columns of the column classest 45 may be arranged around the shart 10, which as shown here forces a portion of the body of the spring daying, with make of the columns fitted in the recen by. The solumns may be

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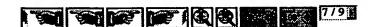




fitted closely together as shown, or may be spaced around the race, with some rators used between them to meintain the Smilered specing. The runher of columns ampliqued will dupord upon column characteristics and the materials of construction. For example, the elementary ratio of the column may be warred riduly, set the column units say be round, filet, filmel or hinged. The preferred ation is a this, element calma with rounded sais, free to sow within the proces shaped to the exemption of the column scale. Materials which may be antisferiority employed for the solumns are carton and her alloy stople, mine statuless stools, various suppor born allegs, such or become, berylline support, the high minhal alloys and other miniber acterials providing setisfactory unchesised properties. Typically, the initvidual columns are or long rectangular cross-contion, with the width bring greater than the thickness, and arranged so that the wider race of the universe is served to the dimenter of the sheft. Thus, with sufficient compression losting, the columns backle, and band shout the axis having the losst someth of inertia, e.g., outwartly ever from the shaft 18.

For example, a group of columns D.167-inch thick by 0.435-inch wide by 10.626-inches long, with the ands roussian, were fabricated from A.I.S.I 4340 start, quantied set draws at 575°F. Buth column was found to require a 20 critical compression loading of 350 pounds in order to backle the column. . After bunkling, the selmms were found to have a very flat spring characteris-Me, as shows in Figure 3, whereis Po is the critical beaking look and point ute the loss and deflection at which the stress in the exhause fibers of the delumn exceed the yield point of the untertal. Theoretically, the shape of this spring characteristic surve is described by surve CA'ANO. Actually, this curve is described by CASC due to friction in the system. Potets A one 2 represent typical straing limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flexing system are not embiddigated, a working stress just below the 30 yield gaint may be used, while with a great number of flaures, the working stress may be held to here then the endurence himit of the enterial of construction. In the above-mentioned tests, the intered deflection was limited to

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approximately one true, at which the longitudinal defloration was approximately 0.225 inches. From more deflection to the accuses deflection, the \$50-pound loading was found to be substantially constant.

In emother test a spring device was built, no shown, employing 80 columns, each faving a critical bushling load of 1250 younds. The interel deflection was limited between 0 and about 1.00 inches by expressionly positioning the steps. Such expressional loading, the spring element bushled at substantially 25,000 possels and from a longitudinal deflection of 0.05 inches (bushling) to shout 0.15 inches the load remained substantially at 25,000

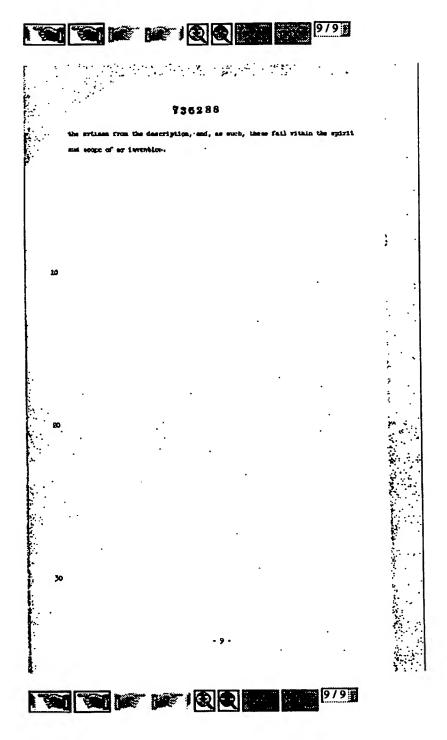
Of course, in dorigining a spring pleaser as above it is educate as to obtain the greatest possible value of longitudinal defloration for specified values of laboral deflocation and article bushling load, while uninterining the atress level is the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures IS and 2, with mittigle flat unwhere mixing to each column.

In wall making, the molecup tool is lowered into the well as mentioned above, with the area 22 in the retreated position. Show the tool is at the desired with the area 22 in the retreated position. Show the tool is at the desired level, the wall tisking to revolved. The frientes makes by tagages with the wall of the energy one prevents thinkle 41 from revolving. With several revolutions of the taking, lower shoulder 35 is moved uponedly by differential energy 39 to bush is opening almost 37 which has a predeferminal critical bushling load. This less is transmitted uponedly against the lower and of expender 35, and its topened surface is engaged with the tagened surface on the incide of the orne 22 to was the term extractly with a substantially constant force proportional to the critical bushling load of the spring almost. Endeaquantly, the expending tool is passed through the liner to append its in the captage in the measur described invalue/ore.

The foregoing description of a preferred embeliant of my investion has been given for the purpose of accomplishmenton. It will be understood that various medicinations in the devoise of association will become apparent to

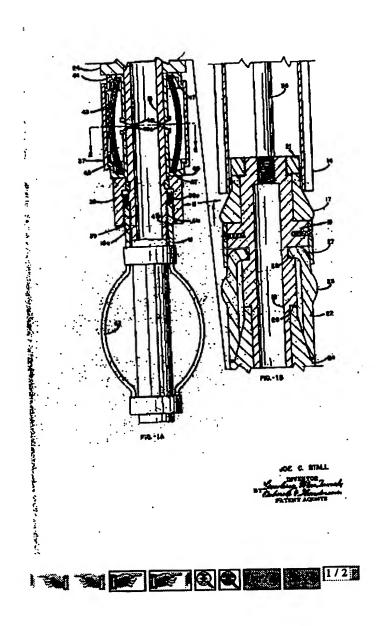
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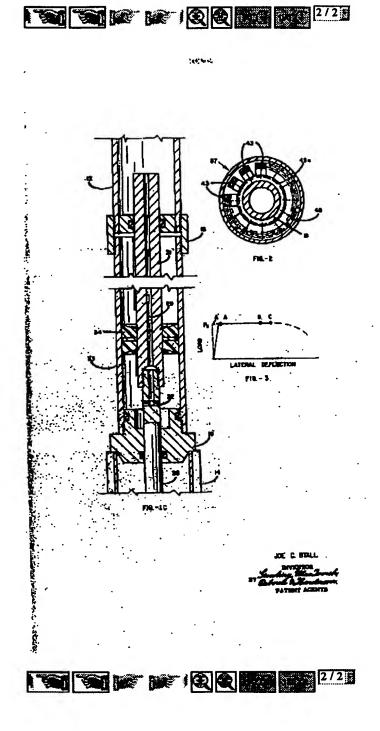
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